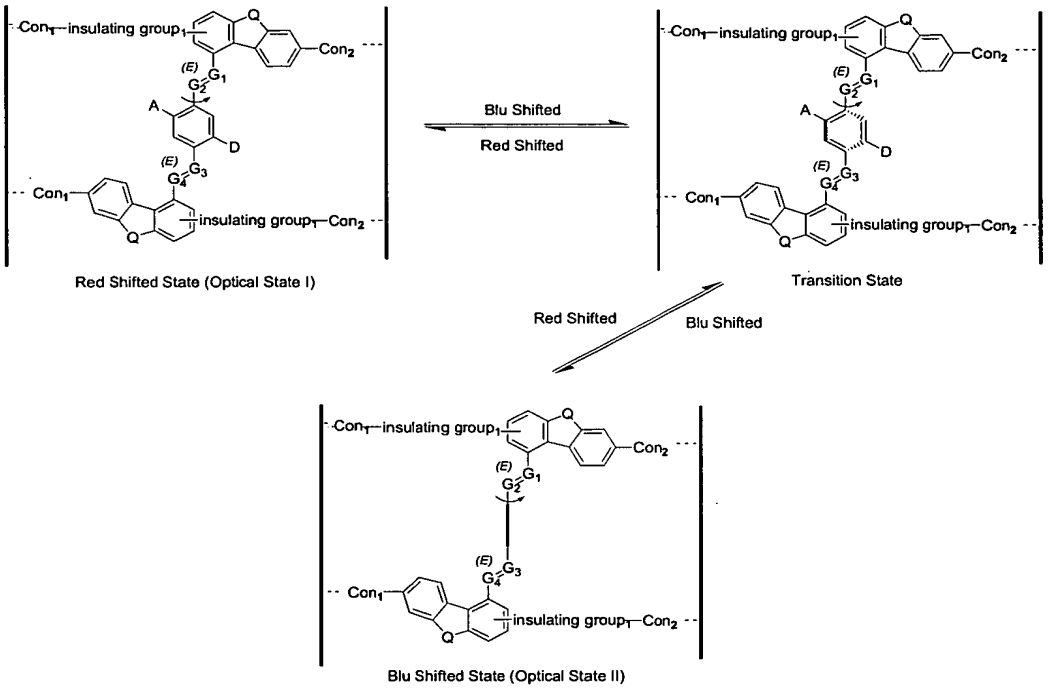
CLAIMS

What Is Claimed Is:

1. An electric field activated optical switch comprising a molecular system configured within an electric field generated by a pair of electrodes, said molecular system having one rotor portion connected between two stator portions, wherein said rotor portion rotates with respect to said stator portions between at least two different states upon application of said electric field, thereby inducing a band gap change in said molecular system, wherein in a first state, there is extended conjugation over at least most of said molecular system, resulting in a relatively smaller band gap, and wherein in a second state, said extended conjugation is destroyed, resulting in a relatively larger band gap.

2. The optical switch of Claim 1 wherein said molecular system has an orientation axis and wherein said rotor portion is oriented perpendicular to said orientation axis, with said external electric field applied parallel to said orientation axis.

3. The optical switch of Claim 2 wherein said molecular system comprises:



where

A is an Acceptor group comprising an electron-withdrawing group selected from the group consisting of: (a) hydrogen, (b) carboxylic acid and its derivatives, (c) sulfuric acid and its derivatives, (d) phosphoric acid and its derivatives, (e) nitro, (f) nitrile, (g) hetero atoms selected from the group consisting of N, O, S, P, F, Cl, and Br, (h) functional group with at least one of said hetero atoms, (i) saturated or unsaturated hydrocarbons, and (j) substituted hydrocarbons;

D is a Donor group comprising an electron-donating group selected from the group consisting of: (a) hydrogen, (b) amines, (c) OH, (d) SH, (e) ethers, (f) saturated or unsaturated hydrocarbons, (h) substituted hydrocarbons, and (i) functional groups with at least one of hetero atom selected from the group consisting of B, Si, N, O, S, P, and I, wherein said Donor group is relatively more electropositive than said Acceptor group;

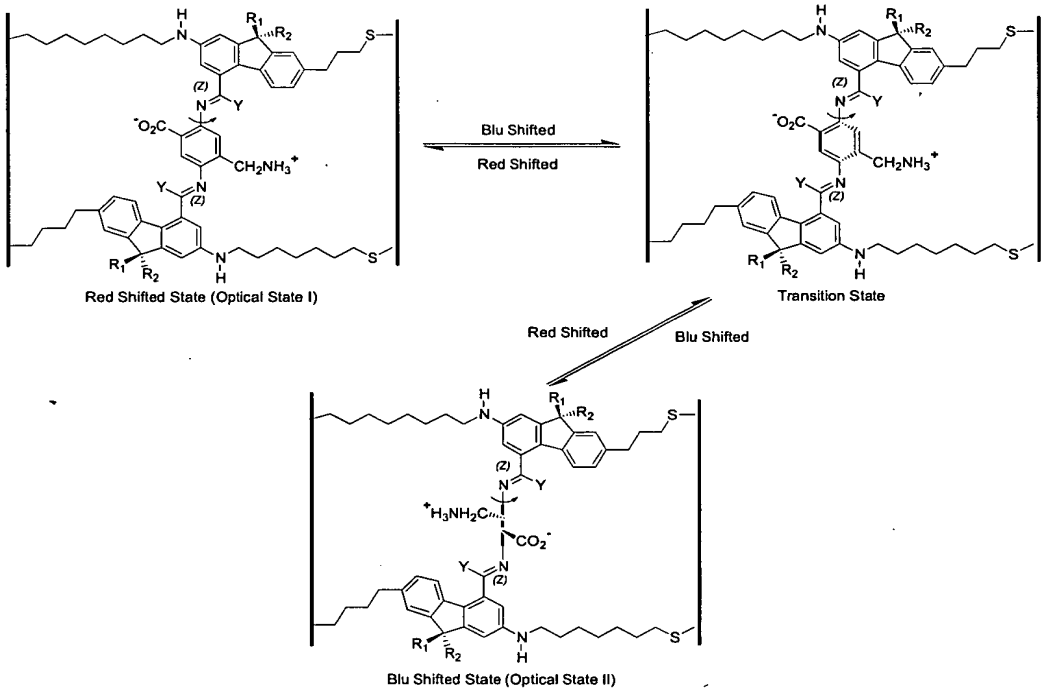
Con_1 and Con_2 are connecting units between one molecule and another molecule or between a molecule and a solid substrate selected from the group consisting of a metal electrode, an inorganic substrate, and an organic substrate, said connecting units independently selected from the group consisting of: (a) hydrogen (utilizing a hydrogen bond), (b) multivalent hetero atoms selected from the group consisting of C, N, O, S, and P, (c) functional groups containing said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (d) substituted hydrocarbons;

G_1, G_2, G_3, and G_4 are bridging groups for connecting said stator to each rotor or to connect two or more conjugated rings to achieve a desired electronic property, said bridging groups selected from the group consisting of: (a) hetero atoms selected from the group consisting of N, O, S, and P, (b) functional groups with at least one of said hetero atoms, (c) saturated or unsaturated hydrocarbons, (d) substituted hydrocarbons, (e) a single atom bridge, and (f) a direct sigma bond between said rotor and each stator; and

Q is a connecting unit between two phenyl rings and is selected from the group consisting of: (a) S, (b) O, (c) NH, (d) NR, (e) hydrocarbon, and (f) substituted hydrocarbon, and

where the vertical thick lines represent said solid substrate to which said molecule is electrically attached.

4. The optical switch of Claim 3 wherein said molecular system comprises:



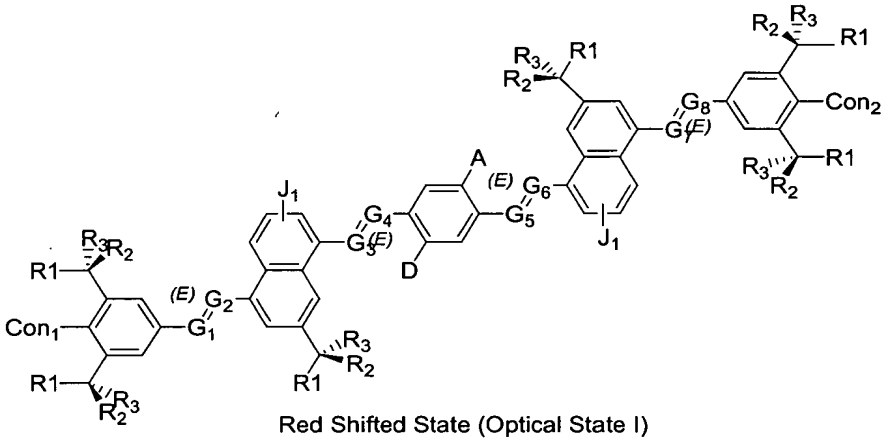
where:

R_1 and R_2 are independently hydrogen hydrocarbon or substituted hydrocarbon; and

Y is selected from the group consisting of hydrogen, OH, SH, hydrocarbon or substituted hydrocarbon.

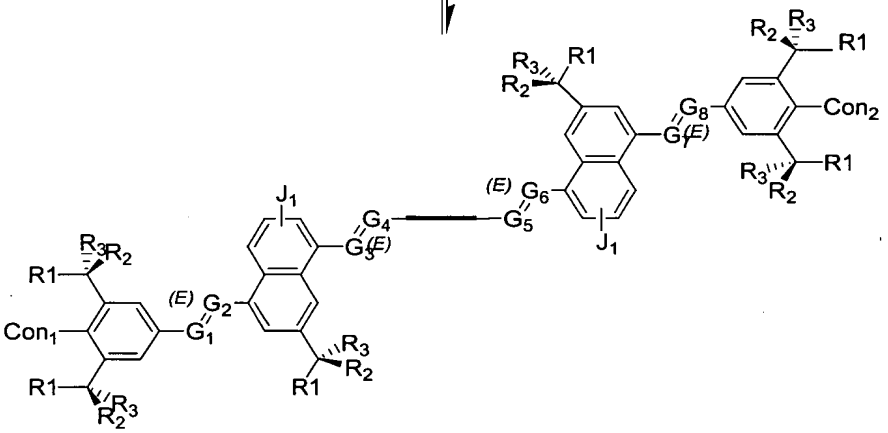
5. The optical switch of Claim 1 wherein said molecular system has an orientation axis and wherein said rotor portion is oriented parallel to said orientation axis, with said external electric field applied perpendicular to said orientation axis.

6. The optical switch of Claim 5 wherein said molecular system comprises:



Red Shifted State (Optical State I)

Red Shifted ⇌ Blu Shifted



Blu Shifted State (Optical State II)

where:

A is an Acceptor group comprising an electron-withdrawing group selected from the group consisting of: (a) hydrogen, (b) carboxylic acid and its derivatives, (c) sulfuric acid and its derivatives, (d) phosphoric acid and its derivatives, (e) nitro, (f) nitrile, (g) hetero atoms selected from the group consisting of N, O, S, P, F, Cl, and Br, (h) functional groups with at least one of said hetero atoms, (i) saturated or unsaturated hydrocarbons, and (j) substituted hydrocarbons;

D is a Donor group comprising an electron-donating group selected from the group consisting of: (a) hydrogen, (b) amines, (c) OH, (d) SH, (e) ethers, (f) saturated and unsaturated hydrocarbons, (g) substituted hydrocarbons, and (i) functional groups with at least one of hetero atom selected from the group consisting of B, Si, N, O, S, P, and I, wherein said Donor group is relatively more electropositive than said Acceptor group;

Con_1 and Con_2 are connecting units between one molecule and another molecule or between a molecule and a solid substrate selected from the group consisting of a metal electrode, an inorganic substrate, and an organic substrate, said connecting units independently selected from the group consisting of: (a) hydrogen (utilizing a hydrogen bond), (b) multivalent hetero atoms selected from the group consisting of C, N, O, S, and P, (c) functional groups containing said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

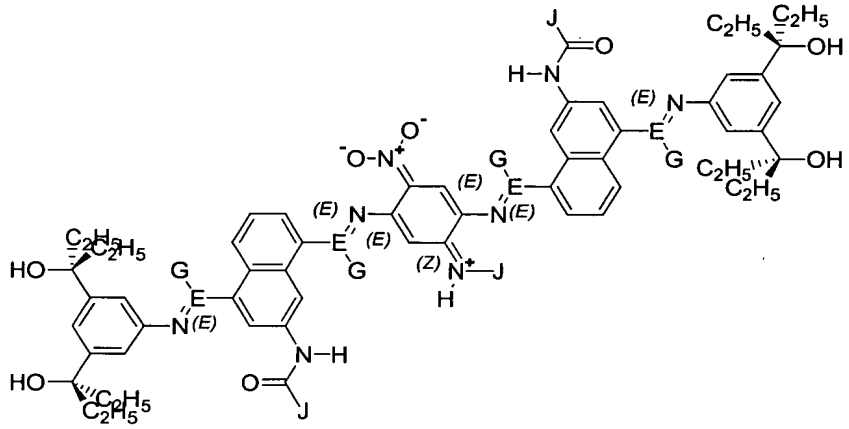
R_1, R_2 and R_3 are spacing groups for providing an appropriate 3-dimensional scaffolding to allow molecules to pack together while providing rotational space for each rotor, said spacing groups selected from the group consisting of: (a) hydrogen, (b) saturated or unsaturated hydrocarbon, and (c) substituted hydrocarbon;

G_1, G_2, G_3, G_4, G_5, G_6, G_7, and G_8 are bridging groups for connecting said stator to each rotor or to connect two or more conjugated rings to achieve a desired electronic property, said bridging groups selected from the group consisting of: (a) hetero atoms selected from the group consisting of N, O, S, and P, (b) functional groups with at least one of said hetero atoms, (c) saturated or un-

saturated hydrocarbons, (d) substituted hydrocarbons, (e) a single atom bridge, and (f) a direct sigma bond between said rotor and each stator; and

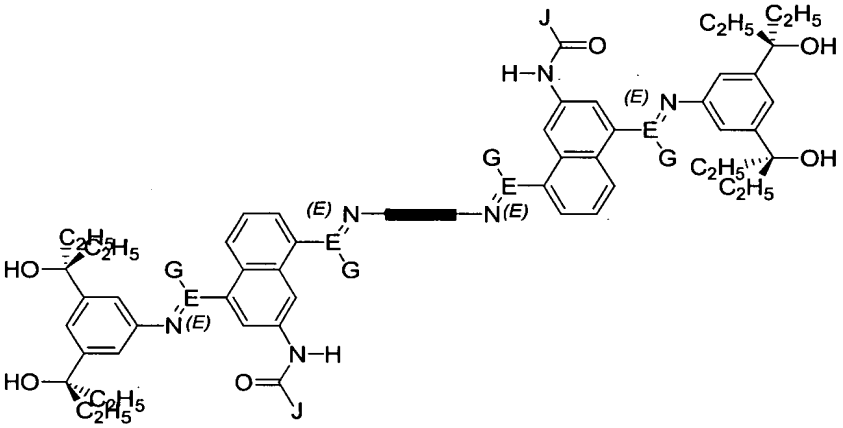
J_1 and J_2 are tuning groups to provide at least one appropriate functional effect selected from the group consisting of inductive effects, resonance effects, and steric effects, said tuning groups being selected from the group consisting of: (a) hydrogen, (b) hetero atoms selected from the group consisting of N, O, S, P, B, F, Cl, Br and I, (c) functional groups with at least one of said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

7. The optical switch of Claim 6 wherein said molecular system comprises:



Red Shifted State (Optical State I)

Red Shifted ⇕ Blu Shifted



Blu Shifted State (Optical State II)

wherein the letters E, G, and J indicate sites where different chemical units can be utilized to adjust geometrical structure and optical properties of said molecular system and have generic designations as follows: E, G, and J are independently selected from the group consisting of hydrogen, heteroatoms, hydrocarbons (either saturated or unsaturated), and substituted hydrocarbons..

8. The optical switch of Claim 1 wherein said molecular system is bi-stable, which provides a non-volatile component.

9. The optical switch of Claim 1 wherein said molecular system has essentially a low activation barrier between different states to provide a fast, but volatile, switch.

10. The optical switch of Claim 1 wherein said molecular system has more than two switchable states, such that optical properties of said molecular system can be tuned by either continuously by application of a decreasing or increasing electric field to form a volatile switch or the color and/or index of refraction is changed abruptly by the application of voltage pulses to a switch with at least one activation barrier.

11. The optical switch of Claim 1 wherein said molecular system changes between a transparent state and a colored state.

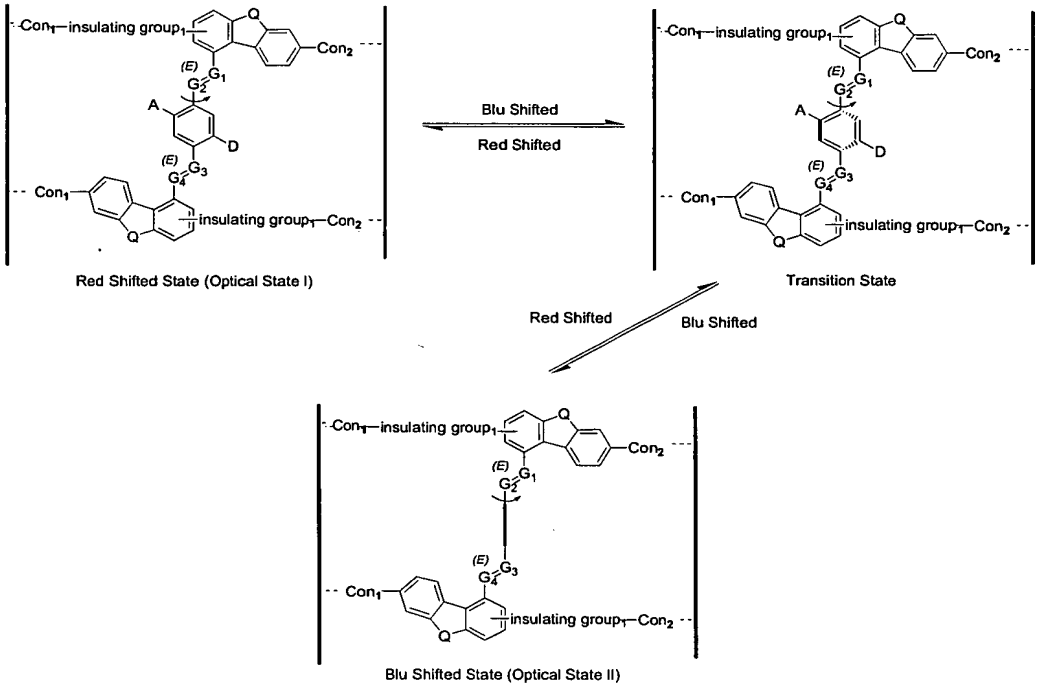
12. The optical switch of Claim 1 wherein said molecular system changes between one colored state and another colored state.

13. The optical switch of Claim 1 wherein said molecular system changes between one index of refraction and another index of refraction.

14. A bi-stable molecular molecular system having one rotor portion connected between two stator portions, wherein said rotor portion rotates with respect to said stator portions between at least two different states upon application of said electric field, thereby inducing a band gap change in said molecular system, wherein in a first optical state, there is substantial extended conjugation throughout said molecular system, resulting in a relatively smaller band gap, thereby forming a "red-shifted state", and wherein in a second optical state, said extended conjugation is destroyed, resulting in a relatively larger band gap, thereby forming a "blue-shifted state".

15. The molecular system of Claim 14 wherein said molecular system has an orientation axis and wherein said rotor portion is oriented perpendicular to said orientation axis, with said external electric field applied parallel to said orientation axis.

16. The molecular system of Claim 15 comprising:



where

A is an Acceptor group comprising an electron-withdrawing group selected from the group consisting of: (a) hydrogen, (b) carboxylic acid and its derivatives, (c) sulfuric acid and its derivatives, (d) phosphoric acid and its derivatives, (e) nitro, (f) nitrile, (g) hetero atoms selected from the group consisting of N, O, S, P, F, Cl, and Br, (h) functional group with at least one of said hetero atoms, (i) saturated or unsaturated hydrocarbons, and (j) substituted hydrocarbons;

D is a Donor group comprising an electron-donating group selected from the group consisting of: (a) hydrogen, (b) amines, (c) OH, (d) SH, (e) ethers, (f) saturated or unsaturated hydrocarbons, (h) substituted hydrocarbons, and (i) functional groups with at least one of hetero atom selected from the group consisting of B, Si, N, O, S, P, and I, wherein said Donor group is relatively more electropositive than said Acceptor group;

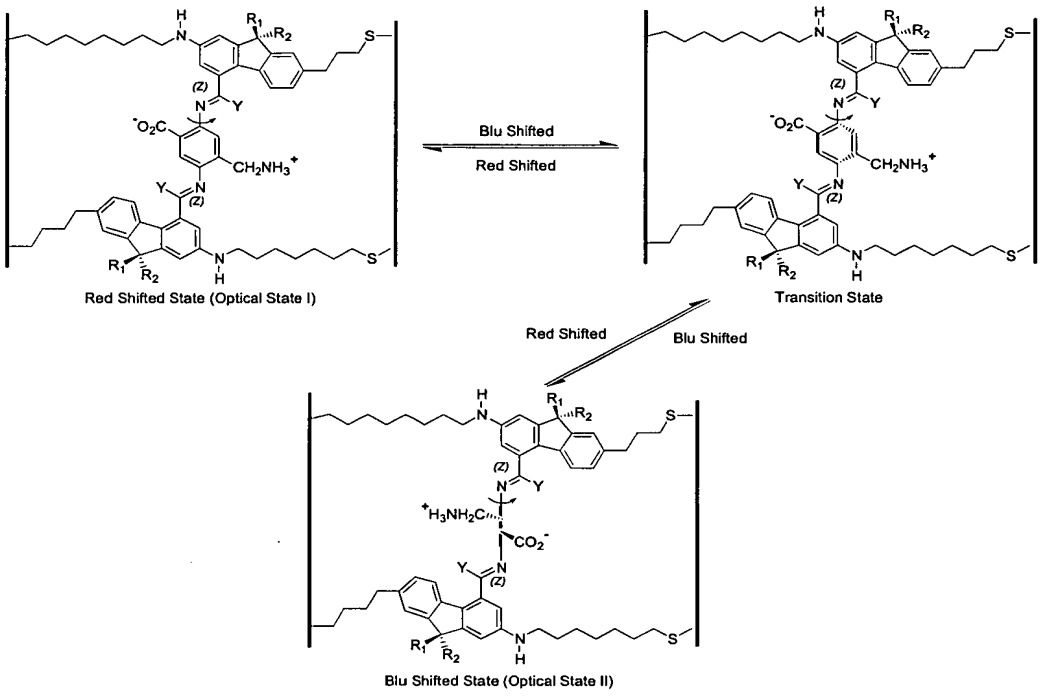
Con_1 and Con_2 are connecting units between one molecule and another molecule or between a molecule and a solid substrate selected from the group consisting of a metal electrode, an inorganic substrate, and an organic substrate, said connecting units independently selected from the group consisting of: (a) hydrogen (utilizing a hydrogen bond), (b) multivalent hetero atoms selected from the group consisting of C, N, O, S, and P, (c) functional groups containing said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (d) substituted hydrocarbons;

G_1, G_2, G_3, and G_4 are bridging groups for connecting said stator to each rotor or to connect two or more conjugated rings to achieve a desired electronic property, said bridging groups selected from the group consisting of: (a) hetero atoms selected from the group consisting of N, O, S, and P, (b) functional groups with at least one of said hetero atoms, (c) saturated or unsaturated hydrocarbons, (d) substituted hydrocarbons, (e) a single atom bridge, and (f) a direct sigma bond between said rotor and each stator; and

Q is a connecting unit between two phenyl rings and is selected from the group consisting of: (a) S, (b) O, (c) NH, (d) NR, (e) hydrocarbon, and (f) substituted hydrocarbon, and

where the vertical thick lines represent said solid substrate to which said molecule is electrically attached.

17. The molecular system of Claim 16 comprising:



where:

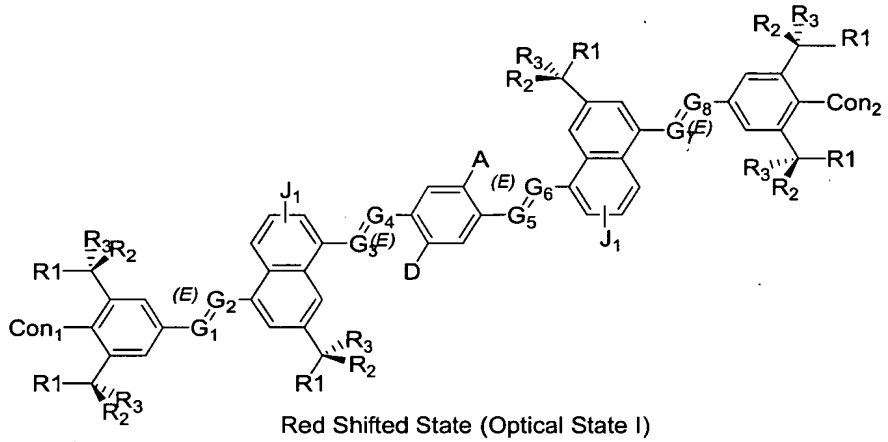
R_1 and R_2 are independently hydrogen, hydrocarbon or substituted hydrocarbon; and

Y is selected from the group consisting of hydrogen, OH, SH, hydrocarbon or substituted hydrocarbon.

18. The molecular system of Claim 14 wherein said molecular system has an orientation axis and wherein said rotor portion is oriented parallel to said orien-

tation axis, with said external electric field applied perpendicular to said orientation axis.

19. The molecular system of Claim 18 comprising:



where:

A is an Acceptor group comprising an electron-withdrawing group selected from the group consisting of: (a) hydrogen, (b) carboxylic acid and its de-

rivatives, (c) sulfuric acid and its derivatives, (d) phosphoric acid and its derivatives, (e) nitro, (f) nitrile, (g) hetero atoms selected from the group consisting of N, O, S, P, F, Cl, and Br, (h) functional groups with at least one of said hetero atoms, (i) saturated or unsaturated hydrocarbons, and (j) substituted hydrocarbons;

D is a Donor group comprising an electron-donating group selected from the group consisting of: (a) hydrogen, (b) amines, (c) OH, (d) SH, (e) ethers, (f) saturated and unsaturated hydrocarbons, (g) substituted hydrocarbons, and (i) functional groups with at least one of hetero atom selected from the group consisting of B, Si, N, O, S, P, and I, wherein said Donor group is relatively more electropositive than said Acceptor group;

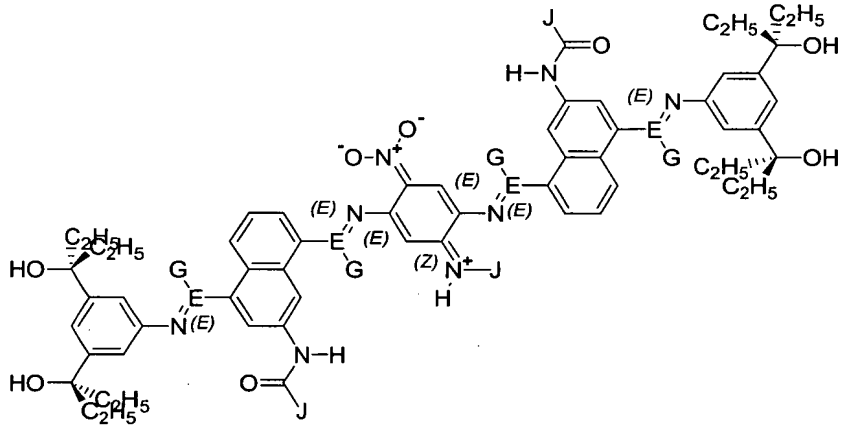
Con_1 and Con_2 are connecting units between one molecule and another molecule or between a molecule and a solid substrate selected from the group consisting of a metal electrode, an inorganic substrate, and an organic substrate, said connecting units independently selected from the group consisting of: (a) hydrogen (utilizing a hydrogen bond), (b) multivalent hetero atoms selected from the group consisting of C, N, O, S, and P, (c) functional groups containing said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

R_1, R_2 and R_3 are spacing groups for providing an appropriate 3-dimensional scaffolding to allow molecules to pack together while providing rotational space for each rotor, said spacing groups selected from the group consisting of: (a) hydrogen, (b) saturated or unsaturated hydrocarbon, and (c) substituted hydrocarbon;

G_1, G_2, G_3, G_4, G_5, G_6, G_7, and G_8 are bridging groups for connecting said stator to each rotor or to connect two or more conjugated rings to achieve a desired electronic property, said bridging groups selected from the group consisting of: (a) hetero atoms selected from the group consisting of N, O, S, and P, (b) functional groups with at least one of said hetero atoms, (c) saturated or unsaturated hydrocarbons, (d) substituted hydrocarbons, (e) a single atom bridge, and (f) a direct sigma bond between said rotor and each stator; and

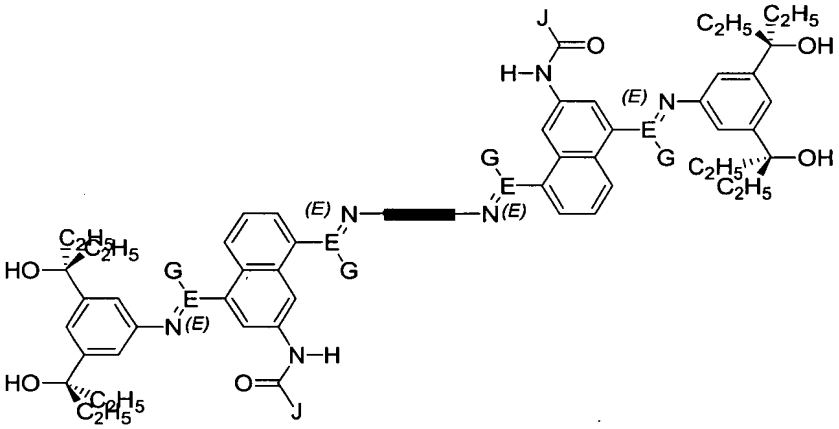
J_1 and J_2 are tuning groups to provide at least one appropriate functional effect selected from the group consisting of inductive effects, resonance effects, and steric effects, said tuning groups being selected from the group consisting of: (a) hydrogen, (b) hetero atoms selected from the group consisting of N, O, S, P, B, F, Cl, Br and I, (c) functional groups with at least one of said hetero atoms, (d) saturated or unsaturated hydrocarbons, and (e) substituted hydrocarbons;

20. The molecular system of Claim 19 comprising:



Red Shifted State (Optical State I)

Red Shifted ⇕ Blu Shifted



Blu Shifted State (Optical State II)

wherein the letters E, G, and J indicate sites where different chemical units can be utilized to adjust geometrical structure and optical properties of said molecular system and have generic designations as follows: E, G, and J are independently selected from the group consisting of hydrogen, heteroatoms, hydrocarbons (either saturated or unsaturated), and substituted hydrocarbons.